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APPLICATION FOR UNITED STATES LETTERS PATENT

FOR

LOCKING APPARATUS WITH PACKOFF CAPABILITY

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CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the priority of U.S. Provisional application serial number 60/413,037 filed September 24, 2002.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0002] The present invention relates to tools for developing and producing fluids from subterranean wells. More particularly, the invention is a wireline or coiled tube positioned locking apparatus for securing the position of a production tube flow control or measurement tool in a landing nipple located in a tubing string having a profile and seal bore specifically prepared to accept the locking apparatus with packing.

DESCRIPTION OF RELATED ART

[0003] A prior art procedure for placing and securing a subterranean well tool at a predetermined position within a well production tube is a special purpose locking apparatus having a collet or locking dogs that are mechanically actuated by surface manipulated wirelines or coiled tubing. Usually, the locking tool is attached to the top of the well tool or instrument and to a wireline running tool. The assembly is lowered into the well at the end of the wireline to the desired depth and location. Radially expandable locking dogs or collets are actuated, for example, by wireline manipulation to engage or mesh with cooperative surfaces, receptacles or profiles within the tubing.

[0004] A common method of positioning a subterranean well tool within a well conduit, such as a tubing string, is to insert a locking apparatus in a landing nipple, the landing nipple being pre-installed at a particular location within the tubing string and containing a profile into which the locking apparatus may engage. The locking apparatus will normally no-go on a shoulder of

the landing nipple and will have means of locking into the profile of the landing nipple using outward expanding members such as dogs or collets.

[0005] Normally associated with the locking apparatus is a set of chevron packing rings to provide a seal between the landing nipple and a well tool attached to the locking apparatus, such as a blanking plug or safety valve. Typically, the packing is positioned in a polished seal bore of the landing nipple, between two fixed limiting shoulders on the locking apparatus and a well tool such as a blanking plug or safety valve. Unfortunately, however, it is not unusual for the seal bores of the landing nipple to be damaged in the well either by wireline cutting (longitudinal grooves) or by general corrosion. Prior art locking devices have not provided a mechanism or procedure to apply axial compressive loading of the packing to improve sealing by extrusion into such grooves pits or imperfections.

[0006] U.S. Patent No. 4,295,528, for example, is a patent for a "Selective Lock with Setting and Retrieving Tools." Element 104 in Fig. 2c of this '528 patent represents a chevron packing unit or assembly installed on the mandrel of the wireline lock in a typical manner. The purpose of the chevron packing is to provide a seal between the mandrel and the seal bore in a landing nipple. However, the chevron packing material is only confined between two fixed shoulders at each end of the packing and has no capacity for operational adjustment.

[0007] Similar fixed or static shoulder confinements for chevron seals are disclosed in U.S. Patents 4,315,544; 4,510,995; 4,583,591; and 4,823,872. U.S. Patents 4,406,324 and 4,993,493 also disclose oilfield equipment that employs chevron packing located between two fixed shoulders. The chevron packing is landed either on the lock mandrel or the tool attached to the lock mandrel and is always trapped between two fixed shoulders that position and confine the chevron packing rings but does not compress them.

[0008] Somewhat different in concept is the locking device described in U.S. Patent No. 5,348,087 which can actually have a seal bore larger than the internal diameter of the tubing string. The locking device contains an elastomeric packing element located on a mandrel. The mandrel contains an enlarged diameter portion which, when driven beneath the packing element, causes the packing element to expand radially and engage the seal bore of the nipple. Due to relative movement of the mandrel, the expanding metal rings on each side of the packing element can not be considered fixed until after the lock is set. After the lock is set, however, they essentially become fixed with respect to the packing element and there is no provision for applying or increasing the end load on the packing element of this device as a means for improving the sealing.

[0009] It is, therefore, an object of the present invention is to provide a locking apparatus having the ability to apply axial compressive loading on a chevron packing or other packing configuration associated with the locking apparatus.

[0010] Another object of the present invention is a means to improve the sealing ability of locking apparatus packing under adverse condition such as mechanical or chemical corrosion damage to seal the bore of the landing nipple or other adverse sealing condition such as high pressure and high temperature.

[0011] Also an object of the present invention to provide a locking apparatus having the ability to apply an axial compressive load to the chevron packing to improve sealing of the packing using conventional wireline manipulation means.

[0012] Another object of the present invention is locking apparatus mechanism having the capacity to apply an axial end load to the chevron seal packing thereby forcing the packing

material into grooves or other imperfection in the seal bore of the landing nipple to effect a seal when otherwise, the seals would leak.

[0013] Also an object of the invention is provision of an ability to apply an axial compressive load to locking apparatus chevron seals to aid in sealing the tubing bore under high pressure, high temperature applications, even when the seal bore in the landing nipple is perfect.

[0014] An additional object of the invention is to provide the means of applying additional axial compressive loading in a remedial action to shut off an existing leak using normal wireline manipulation means.

SUMMARY OF THE INVENTION

[0015] The invention provides an ability to apply a compressive, axial loading on the chevron packing to expand the packing material radially thereby forcing the chevron packing material into the grooves, pits or other imperfections in the seal bore of the landing nipple and thereby effecting a seal when otherwise, the seal would leak.

[0016] To these ends, the present well tool locking connector includes an interior packing mandrel having a first cylindrical surface that carries a compression expanded packing ring that is axially confined along the packing mandrel first surface by an compression abutment shoulder. An axial extension of the packing mandrel transitions over a ramped shoulder onto a second, lesser diameter cylindrical surface. At least a portion of the second cylindrical surface extended from the ramped shoulder is profiled with directionally biased channels such as buttress threads. A body lock ring having a correspondingly profiled I.D. meshes with the packing mandrel surface profile.

[0017] Further along the packing mandrel extension from the ramped shoulder and the meshed locking ring is a fishing tool connection surface such as a locking dog receptacle detent or channel or a fishing barb ring.

[0018] Between the fishing tool connection surface and the meshed locking ring, a control sleeve slidably overlies the packing mandrel extension. The control sleeve also includes a fishing tool connection surface such as that used for the packing mandrel, preferably. Distal from the fishing tool connection, the control sleeve includes an abutment shoulder band having an O.D. shoulder in facing proximity with the fishing tool connection and an I.D. shoulder in facing proximity with the locking ring. The I.D. shoulder of the control sleeve is axially recessed from a retaining ring abutment shoulder.

[0019] A locking dog caging sleeve slidably overlaps the first cylindrical surface of the packing mandrel and the control sleeve abutment shoulder band. An end of the caging sleeve lapped upon the first cylindrical surface of the packing mandrel proximate of the packing ring is a compression ram. An opposite distal end of the caging sleeve includes a I.D. abutment shoulder in facing proximity with the O.D. abutment shoulder of the control sleeve. One or more locking dogs are confined by caging slots in the caging sleeve. A radially expandable retaining ring provides a preset connection between the body lock ring and the caging ring.

[0020] A preset alignment of the tool components is secured by calibrated shear fasteners. Such preset alignment provides a retracted position for the locking dog or dogs and an uncompressed packing ring for well run-in. When suspended at the end of a suitable suspension structure such as a wireline or coiled tubing, for location within a well, the fishing tool engagement surfaces respective to the packing ring mandrel and the control sleeve are axially separated by a first manipulation of the suspension structure to translate the packing ring mandrel relative to the

caging sleeve and the control sleeve. This translation draws the ramped shoulder of the mandrel under or in radial contiguity with the locking dog thereby causing a radial displacement of the locking dog or dogs into a well tubing receptacle or detent channel. Simultaneously, the packing ring is compressed between the mandrel compression shoulder and the ram end of the caging sleeve. Such compression expands the sleeve radially to a pressure sealing engagement with the inside bore wall of the well tube.

[0021] When the packing mandrel is drawn against the control sleeve, the buttress threads are translated under the lock body ring to rectify the movement and secure the compressed position.

[0022] At this point, the tool connector is locked and sealed with the tubing bore. The suspension structure may be released from the fishing tool connection surfaces and withdrawn from the well for replacement by other tools, if desired.

[0023] When release of the well tool from the tubing is desired, fishing tools reengage the mandrel and control sleeve. A second manipulation of the suspension structure translates the control sleeve from abutted engagement of the respectively facing abutment surfaces. This translation of the control sleeve also extracts a spacing hood portion of the control sleeve from between the retaining ring and the caging sleeve thereby permitting it to expand out of linkage engagement between the lock ring and the caging sleeve. A third manipulation of suspension structure translates the first cylindrical surface of the mandrel from under the locking dog or dogs thereby permitting a radial retraction of the dog from the tubing channel. The same mandrel translation decompresses the packing ring.

BRIEF DESCRIPTION OF DRAWINGS

[0024] For a thorough understanding of the present invention, reference is made to the following detailed description of the preferred embodiments, taken in conjunction with the accompanying drawings in which like reference characters designate like or similar elements throughout the several figures of the drawing.

[0025] **Figure 1** is a sectioned view of a locking apparatus in operative assembly with a running tool set for well run-in.

[0026] **Figure 2** is a sectioned view of a locking apparatus in operative assembly with a running tool in an intermediate well setting condition.

[0027] **Figure 3** is a sectioned view of a locking apparatus in operative assembly with a running tool in a set and sealed condition within a well production tube.

[0028] **Figure 4** is a sectioned view of a locking apparatus in operative assembly with a running tool where the locking apparatus is in a set and sealed condition and the running tool is released from the locking apparatus.

[0029] **Figure 5** is an enlarged sectioned view of the locking apparatus configured for well run-in.

[0030] **Figure 6** is an enlarged sectioned view of the locking apparatus configured for a locked and sealed setting within a well production tube.

[0031] **Figure 7** is an enlarged sectioned view of the locking apparatus configured for release from a well production tube.

[0032] **Figure 8** is an enlarged sectioned view of the packing seal portion of the locking apparatus.

[0033] **Figure 9** is an enlarged sectioned view of an alternative packing seal assembly.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0034] A first embodiment of the invention is represented by **Fig. 1** to include a running tool **10** attached to a wireline lock **20**. The running tool **10** comprises An inner mandrel **12** that may be a threaded assembly of several sections to provide a structurally continuous tube element that extends between a threaded box end **13** and a threaded pin end **14**. Optionally, the pin end may also include a fishing neck **15**. A running tool housing **30** is releasably secured to the mandrel **12** by a calibrated failure element such as a shear pin **32**. The housing **30** is secured to the mandrel **12** at such a position as to provide translational space **62** between the sleeve end **35** and a mandrel abutment shoulder **64**. The translational space **62** is covered by a housing extension sleeve **36**. Opposite from the extension sleeve **36**, the housing further includes a control dog housing **66**. The control dog housing has a control dog detent channel **37** for cooperation with a control dog element **38**. Additionally, the control dog housing provides a multiplicity of caging slots **41** for fishing neck dogs **40**.

[0035] When free of the locking dog **38**, the control dog housing **66** may slidably translate along a spring mandrel **16**. A compression spring **17** is seated between the shoulder **68** on the control dog housing **66** and the spring seat shoulder **18** on the spring mandrel **16**. The bias of spring **17** is to separate the respective spring seats and translate the spring mandrel end **70** into the space **72**.

[0036] The outside perimeter of the inner mandrel **12** is profiled to provide a locking dog retraction channel **75** on one side of a locking dog support band **77** and a ramped shoulder **79** on the other side.

[0037] The inside perimeter of the spring mandrel **16** is profiled to provide a ramped shoulder **80** to cooperatively engage the ramped shoulder **79** on the inner mandrel **12**. The outside perimeter of the spring mandrel **16** is also profiled with a ramped shoulder **82** for cooperative engagement with a corresponding inside shoulder ramp **90** near the end of the control dog housing **66**.

[0038] Respective to **Figs. 1** and **5**, the primary structural element of the locking apparatus **20** is the packing mandrel **22** which includes the mandrel sleeve extension **25**. The packing mandrel directly supports a chevron packing **28** against a compression shoulder **84**. One or more shear pins **34** releasably secure the packing mandrel **22** to the running tool spring mandrel **16**. Box threads **27** secure the locking apparatus to additional elements of the tool assembly that are to be secured within the production tube. The inside perimeter of the packing mandrel sleeve extension **25** accommodates a fishing tool connection channel **44**.

[0039] With respect to **Fig. 5**, the outer profile of the mandrel sleeve extension **25** is stepped to provide an elongated groove channel between an abrupt shoulder **86** and a ramped shoulder **88** on the packing mandrel **22**. Between the shoulders **86** and **88**, the outside surface of the ring channel is grooved by, for example, buttress threads or rings **48**. A lock ring **56** has corresponding buttress threads around its inside circumference to mesh with the threads **48**. The lock ring **56** is an expansible hoop spring that will accommodate radial expansion to advance axially in one direction over the buttress threads **48** but opposes movement in the opposite axial direction.

[0040] A control sleeve **46** is slidably confined within the groove extension channel between the abrupt shoulder **86** and the lock ring **56**. The end of the control sleeve proximate of the abrupt shoulder **86** has a threaded connection with a lock assembly sleeve **23** whereby both elements function dynamically as an integral structure.

[0041] The control sleeve **46** also includes a hood extension **49** that projects over the lock ring **56**. The hood extension **49** includes a counterbored shoulder that confines a retainer ring **58** against an end shoulder of a locking dog cage **52**. The retainer ring **58** is an expansible hoop spring that is biased to expand against the inside surface of the hood extension **49**.

[0042] An extension **54** of the locking dog cage **52** laps over the control sleeve **46** and the hood extension **49**. The distal end of the cage extension **54** is rimmed to provide an outside abutment face **55** and an inside abutment shoulder **57**. The locking dog cage **52** laps onto the outside packer seal surface of the packer mandrel **22** to cover a translational space **59** between the ramped shoulder **88** of the of the mandrel **22** and the lock ring **56**. Within the locking dog cage **52** are a plurality of locking dogs **50** that are confined by slots to radial movement into and out of the translational space **59**. A corresponding translational space **96** is provided between the inside abutment shoulder **57** and a control sleeve shoulder **47**. A calibrated failure fastener **60** such as a shear screw secures an initial axial relationship between the locking dog cage **52** and the control sleeve **46**. A safety fastener **24** between the lock assembly sleeve **23** and the packing mandrel sleeve **25** also provides alignment security during transport to the well location. The safety fastener **24** is removed, however, after the locking apparatus **20** is assembled to the running tool **10** but before it is inserted in the well.

[0043] Preparatory to well descent, the wireline lock tool **20** is assembled with the running tool **10** in the manner illustrated by **Fig. 1.** The inner mandrel **12** of the running tool is secured to the sleeve **35** end of the housing **30** by the upper shear pin **32**. An end thread on the mandrel **12** secures it to a tool joint pin **14** to facilitate connection of the assembly to a well suspension structure such as a wireline or coiled tubing.

[0044] The spring mandrel **16** is aligned along the inner mandrel **12** length to position the locking dog support band **77** under the control dog **38** thereby meshing the control dog **38** into the detent ring **37** in the control dog housing **66**. This meshing of the control dog **38** in the housing **66** detent ring **37** immobilizes the spring mandrel **16** with the housing **30** and hence, due to the upper shear pin **32**, with the inner mandrel **12**.

[0045] The lower end of the running tool **10** penetrates the central bore of the locking apparatus **20** to receive the lower shear pin **34** through the spring mandrel **16**. This calibrated shear failure assembly is supplemented by the meshed engagement of the fishing neck dog **40** with the detent channel **42** in the lock assembly sleeve **23**. The meshed engagement of the fishing neck dog **40** is supported by the outside surface of the spring mandrel **16**.

[0046] Before the assembly enters the wellhead, the safety fastener **24** is removed. The locking apparatus **20** remains mechanically linked to the running tool **10** by the fishing neck dog **40** and the lower shear pin **34**.

[0047] Upon alignment with the desired downhole location, the assembly is "jarred" to shear the upper shear pin **32**. That event allows the running tool housing **30** to translate along the inner mandrel **12** and close the translational space **62** as illustrated by **Fig. 2**. This axial downward shifting of the inner mandrel 12 with respect to the housing 30 also translates the control dog support land 77 downward out from underneath the control dogs 38 allowing the control dogs 38 to drop into the locking dog retraction channel 75. Alignment of the control dog **38** with the retraction channel **75** allows the control dog **38** to be radially displaced within the control dog cage of the spring mandrel **16** and out of the detent channel **37** in the control dog housing **66**.

[0048] Retraction of the control dogs **38** from the control dog housing **66** releases the spring mandrel **16** relative to the housing **30** but does not release the spring mandrel from the packing

mandrel **22** of the locking apparatus **20** due to the lower shear pin **34**. Support linkage is also maintained by the fishing neck dog **40** engagement with the detent channel **42** in the lock assembly sleeve **23** and the abutment of shoulders **82** and **90** on the spring sleeve and control dog housing, respectively.

Furthermore, the control dog housing **66** is biased downward against the lock assembly sleeve **23** while the spring mandrel **16**, connected by lower shear pin 34 to the packing mandrel 22, is biased upward, both due to the urging of the compression spring 17. Consequently, when the control dogs 38 are released from the control dog housing 66, the upward bias of the spring mandrel 16 lifts the packing mandrel 22 while holding the lock assembly sleeve 23 down thereby causing a compressive closure between the packing mandrel 22 and the locking dog cage 52 shown by Fig 3. As the ramped shoulder 88 of the packing mandrel 22 engages with the locking dogs 50, the locking dogs are radially displaced into a dog receptacle channel **102** in the landing nipple **100** component of the well fluid production tube thereby securing the locking apparatus **20** to the landing nipple **100** by a mechanical interference as is illustrated by **Figs. 3** and **4**.

[0049] Continued expansion of the spring 17 by compression of the packing ring **28** displaces the spring mandrel **16** relative to the control dog housing **66** until the support land **92** portion of the spring mandrel **16** passes from under the fishing neck dog **40**. As the ramped shoulder **82** passes the fishing neck dog **40** (Fig. 6), the dog **40** drops from the detent channel **42** thereby releasing the running tool **10** from the locking apparatus at that point. However, the shear pin connection **34** between the spring mandrel **16** and the packing mandrel **22** remains.

[0050] With the locking apparatus thus secured to the landing nipple, additional upward jarring movement of the inner mandrel **12** as shown by **Fig. 4** causes the upward facing bevel at the lower end of the control dog retraction channel **75** to engage the inner bevel of the control dogs

38. With the inner mandrel **12** in physical abutment with the control dogs **38**, such subsequent upward jarring shears the lower shear pin **34** to complete the release of the running tool **10** from the locking apparatus **20**. Before the running tool release sequence is complete, however, the process imposes maximum compressive load against the chevron packing ring **28** between the ram end **53** of the locking dog cage **52** and the compression shoulder **84** of the mandrel **22**. When compressed axially, the packing ring expands radially out to a pressure sealed engagement with the landing nipple I.D. **104**. Upon shear failure of the pin **34**, the running tool **10** is released from the locking apparatus **20** and may be removed from the well.

[0051] Also before the release sequence is complete, as the packing mandrel **22** is drawn against the relatively fixed position of the locking dogs **50** and cage **52**, the sleeve **25** also advances the buttress threads **48** on the outer surface of the packing mandrel sleeve **25** under the lock ring **56**. Fig. 6. As long as the retainer ring **58** remains engaged with the lock ring **56**, displacement of the packing mandrel **22** relative to the locking dog cage **52** and control sleeve **46** is unidirectional. The buttress thread bias between the mandrel threads **48** and lock ring **56** prevents a reverse movement. Hence, the locking dogs **50** and packer seal **28** are secured at the engagement position with the landing nipple **100**.

[0052] Displacement of the packing mandrel sleeve **25** relative to the control sleeve **46** also opens a translational space **87** shown by Fig. 6 between the abrupt shoulder **86** on the packing mandrel sleeve **25** and the stepped end of the control sleeve **46**. This translational space **87** will come into use for eventual retrieval of the locking apparatus **20**

[0053] Retrieval of the locking tool may be accomplished by a fishing tool not illustrated but of construction and operation as is well known to the prior art. In particular, such fishing tools have

two or more sets of axially translated fishing dogs carried by either a wireline or continuous tube workstring. Such fishing dogs are of common use in the industry.

[0054] Applied to the present invention, one set of such fishing dogs is manipulated to engage the outer detent channel **42** in the lock assembly sleeve **23**. An inner fishing dog set engages the inner detent channel **44** in the packing mandrel sleeve **25**. The lock assembly sleeve **23** has a threaded connection to the control sleeve **46** and when translated by force exerted by the outer fishing dog set on the outer detent channel **42**, the screw **60** that links lock assembly sleeve **25** to the packing mandrel sleeve **25** fails and the control sleeve shoulder **47** is shifted against the inside abutment shoulder **57** on the end of the cage extension **54**.

[0055] Translation of the control sleeve **46** withdraws the radial structure support of the hood extension **49** from the retainer ring **58** as shown by Fig. 7. Consequently, the retainer ring expands against the inside diameter of the cage extension **54**. When expanded, the retainer ring **58** no longer links the locking dog cage **52** to the lock ring **56** and the packing mandrel sleeve **25**. Hence, the packing mandrel sleeve **25** may be shifted by force applied with inner fishing dogs to the inner detent channel **44**. This packing mandrel shift is oriented toward axial separation of the compression shoulder **84** from the ram end **53** of the locking dog cage **52**. Hence, the seal surface **26** supporting the locking dogs **50** engagement with the landing nipple **100** is withdrawn and the locking dogs **50** are radially free to contract against the O.D. surface of the packing mandrel **22**. Consequently, the locking apparatus **20** is released from mechanical interference engagement with the landing nipple **100** and may be withdrawn from the well.

[0056] **Figure 8** is a close-up view, depicting in greater detail the packing sleeve **28** of the locking apparatus **20**. As shown, the packing sleeve **28** includes a pair of metal end rings **110**, **112** at either axial end, and a central metal ring **114**. A stack of elastomeric chevron rings **116**,

118 is disposed axially between each of the end rings **110**, **112** and the central ring **114**. Each of the chevron rings **116**, **118** has a peaked, generally V-shaped cross-section that is apparent from **Figure 8**. When the ram end **53** compresses the packing sleeve **28**, the chevron rings **116**, **118** are flattened out such that the peaked V in their cross-section is substantially removed.

[0057] **Figure 9** is an enlarged cross-sectional view of portions of locking device **20** incorporating an alternative axially compressible seal assembly **120** for use as packing sleeve **28**. The compressible seal assembly **120** is known commercially as a "Dynamic Seal Assembly" available from Baker Hughes Incorporated. As the structure and function of this seal assembly is well known, it will not be described here. Other suitable seal assemblies may also be utilized as or within the packing sleeve **28** in accordance with the present invention, including seal assemblies that incorporate, for instance, axially compressible hat rings and/or U-cups.

[0058] The preferred invention embodiment has been described to function with expanding dog fishing tools to engage the detent channels **42** and **44**. Those of skill in the art will understand that external fishing connectors that accept and connect with overshot fishing tools may obviously be substituted for the internal connectors **42** and **44**.

[0059] Although the invention has been described in terms of particular embodiments which are set forth in detail, it should be understood that this is by illustration only and that the invention is not necessarily limited thereto. Alternative embodiments and operating techniques will become apparent to those of ordinary skill in the art in view of the present disclosure. Accordingly, modifications of the invention are contemplated which may be made without departing from the spirit of the claimed invention.